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The Electrochemical Industries of Niagara Falls

Joseph William Richards

NIAGARA AS AN ELECTROCHEMICAL CENTRE.

THE ELECTROCHEMICAL INDUSTRIES OF NIAGARA FALLS.

BY JOSEPH W. RICHARDS, PH.D.

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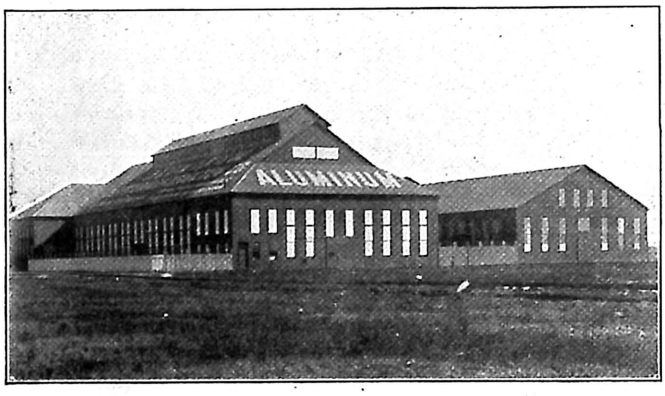
(Concluded.)

THE PITTSBURG REDUCTION CO.

THIS company were organized in 1888, by the late Capt. A. E. Hunt, to work the Hall process of producing aluminum. The chief investors were the Mellon Bank of Pittsburg and Messrs. Hunt and Clapp, of the Pittsburg Testing Laboratory. At present, R. B. Mellon, of Pittsburg, is president; Charles M. Hall and G. H. Clapp, vice-presidents; Arthur V. Davis, secretary and general manager. Originally, $20,000 was subscribed to start the company, but at present the capitalization of the company is $600,000 of 6 per cent. preferred stock and $1,000,000 ordinary stock, paying 8 per cent. Mr. Hall lives at Niagara and has charge of the operation of the Niagara works.

There are two plants of this company at Niagara: the upper plant, situated on the grounds of the Niagara Falls Power Co.,



UPPER WORKS, PITTSBURG REDUCTION CO.

above the falls, and using 4,000 horse-power; the lower, situated on the edge of the gorge below the falls, and taking 6,500 horse-power from the Hydraulic Power and Mfg. Co.

The upper plant is situated half a mile above the upper power house, on a 10-acre plot of ground, and was the first plant to utilize this upper power. When, in 1893, the Niagara Falls Power Co. completed their power house, the next step of finding customers for the power was not easily solved, and special inducements were made to the Pittsburg Reduction Co. to break the ice and become the first plant to utilize this power. The offer took the shape of a contract to furnish the direct current needed for the process, at a certain price per horse-power per year, which price is a private matter between the two companies, but is understood to be not over $18 per horse-power-year. This necessitated the installation by the power company of transformer machinery, at the reduction plant, which is owned and operated by the power company. This is, as far as is known to the writer, the only case in which this power company have furnished the current transformed to suit the customer's purpose, all subsequent contracts being at $18 to $20 per horse-power per year for the alternating current at 2,250 volts, the purchasers putting in and operating their own transformer machinery.

The alternating current is first passed through a set of twelve air-cooled stationary transformers, which reduce its potential to 115 volts and raise its ampèrage correspondingly, with a loss in conversion of 3 per cent. It then passes to rotary transformers, of which there are six each of 800 horse-power, which transform the alternating current of 115 volts into direct current at 160 volts, with another loss of 3 per cent. in conversion. Five of these, run to full capacity, furnish two currents of approximately 10,000 ampères by 160 volts each; sometimes all six are run, at five-sixths full capacity, to furnish the same current.

Each current passes through a line of reducing pots, being conducted on aluminum bars, 12 inches by 1 inch, giving a carrying capacity of over 800 ampères per square inch of conductor. The bars are not insulated, the low voltage rendering that unnecessary. The voltage drop at each pot is a little over 5 volts, each pot absorbing about 65 horse-power. The current passes into each pot through carbon electrodes, 3 inches diameter by 18 inches long, each carrying 250 ampères of current. It is found that this is about the maximum current which can be carried by the copper-rod connections without undue overheating. About one-half the energy of the current is absorbed in the chemical work of decomposing alumina, the other half is converted into heat and keeps the bath at the proper temperature and fluidity necessary for electrolysis—about 850° to 900° Centigrade. The efficiency of recovery reckoned on the ampères used is between 80 and 90 per cent. The bath is the ordinary Hall bath, containing cryolite, to which is added aluminum fluoride, as the solvent, and with alumina dissolved therein. The action of the current sets free aluminum and oxygen, the latter uniting with the carbon anodes to carbonic oxide. Although 4,000 horse-power are being used, the smell of fluorine is usually not perceptible in the pot room, except during casting or trimming up a pot. The aluminum obtained averages 0.1 per cent. iron, 0.3 per cent. silicon, with smaller amounts of copper, titanium, carbon and sodium, but is guaranteed over 99 per cent. pure, averaging more nearly 99.5 per cent. The selling price of such metal is, in ton lots, 31 cents per pound; less pure metal is made from less pure alumina, and sold, for use in casting iron and steel, at 2 cents per pound less.

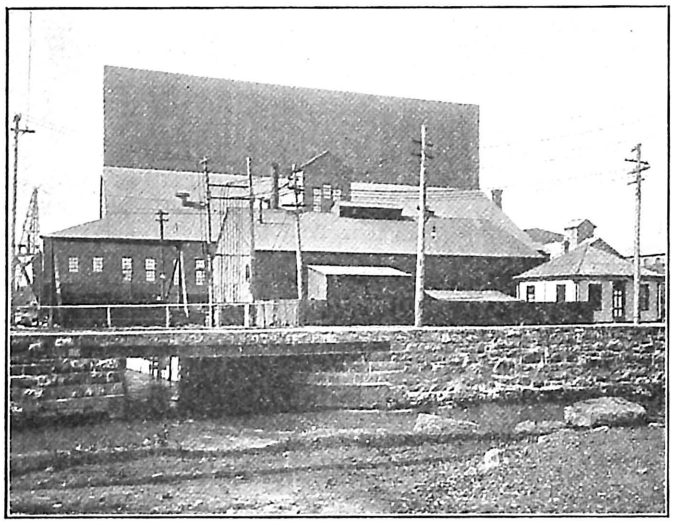
The main reduction room is an iron building, 180 by 85 feet, with a high roof. The windows are whitened by the hydrofluoric fumes occasionally escaping, but the fumes in the building are seldom strong enough to be perceptible. The metal is run into rough ingots, weighing 20 pounds each, and the total output from this plant must be in the neighborhood of 7,200 pounds daily. The crude ingots are shipped to New Kensington, Pa., to be remelted and converted into commercial shapes.

Alongside this main room is a building of equal area, but not so high, in which are kept the stock of metal, and also stocks of alumina and carbons. It contains furnaces for baking the carbon lining in the pots, and machinery for drilling and repairing the carbon electrodes. There is also a well-equipped laboratory, presided over by Wm. T. Whitten, with several assistants.

The company own large deposits of bauxite, the native hydrous aluminum oxide, in Georgia and Alabama.

In 1900 Mr. Hall invented an entirely new method of commercially purifying alumina (U. S. Patents 677,207, 677,208, 677,209, of June 25, 1901), which will receive its first commercial application at Niagara Falls. The bauxite is mixed with sufficient reducing agent, such as carbon, to reduce all the impurities in it to the metallic state, *i. e.*, silica to silicon,

titanic oxide to titanium, iron oxide to iron. The mixture is then melted in an electric furnace, using a carbon pole, the material itself being fed into the arc, and the melted alumina constituting the other pole. An alternating current of low voltage is used. The impurities collect as a metallic alloy of iron, titanium and silicon, while the purified alumina above is almost chemically pure. The furnace is let cool and the contents separated when cold. It is estimated that in this way the bauxite can be purified at less cost than by the wet, chemical processes. The alumina produced is granular, heavy, dissolves well in the pots and produces a metal of high purity.



LOWER WORKS, PITTSBURG REDUCTION CO.

The lower plant of the Pittsburg Reduction Co. is situated on the edge of the gorge, one-quarter mile below the steel bridge, and immediately above the power house of the Hydraulic Power and Mfg. Co. The current is generated in the power house, as direct current, by means of Westinghouse dynamos of 750 horse-power each, coupled direct to turbines with horizontal shafts, the current being conveyed on aluminum cables, of 28 square inches sectional area, a distance of 250

THE CARBORUNDUM CO.

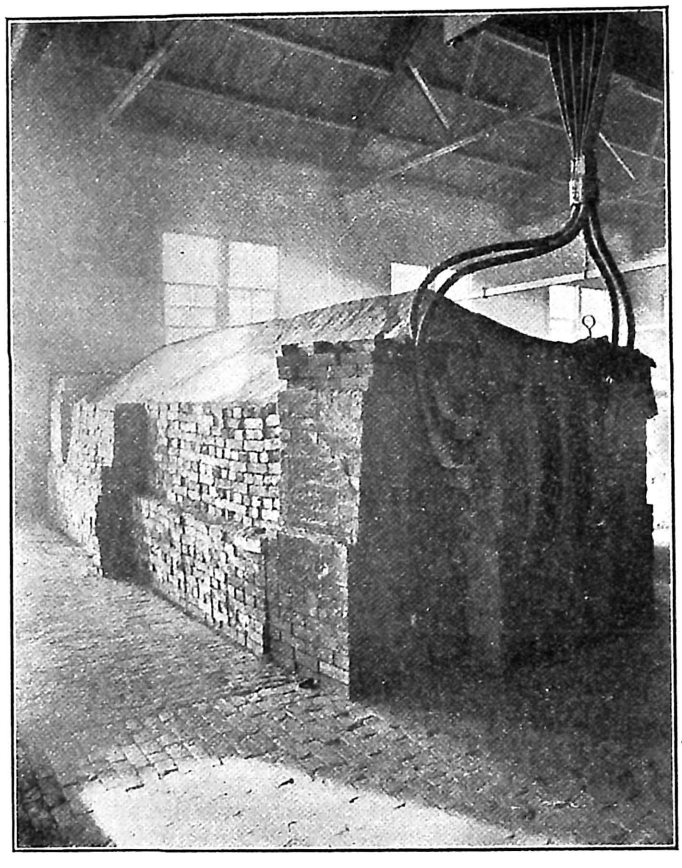
feet to the reduction room on the bank. Each dynamo gives a direct current of 2,000 ampères, at a potential of 280 volts, and nine such machines furnish the 6,500 horse-power necessary to run three lines of pots (2 lines are run at the upper works by 4,000 horse-power). The method of reduction is exactly the same as at the upper plant, and the output approximately 50 per cent. greater, making the total output of both plants probably 19,000 pounds per day. The building has its roof extended into an enormous ventilator, giving it the appearance of a grain elevator, but this greatly increases the comfort of the workmen. No other work than reduction is performed here, for which a force of about 150 men, working in eight-hour shifts, suffices. At the upper works the force is about 200.

Besides these works this company have recently extended their plant by the installation of 5,000 horse-power at Shawinigan Falls, Quebec, and the acquisition of 12,000 horse-power and 100 acres of ground at Massena, N. Y., on which an aluminum plant will be erected. Our congratulations to the enterprising pioneers of the aluminum industry in America!

The Carborundum Co.

This company also owe their organization to Pittsburg capitalists, who in 1893 organized them to work the processes of A. G. Acheson for producing carborundum. The present officers are: F. W. Haskell, president; F. J. Tone, works superintendent, and among the larger stockholders are A. W. and R. B. Mellon, Pittsburg; A. G. Acheson and G. R. Rayner, Niagara Falls.

Carborundum is carbon silicide, CSi, and is formed by intensely heating, in an electric furnace, a mixture of carbon, sand and salt. Mr. Acheson first made it while trying to melt

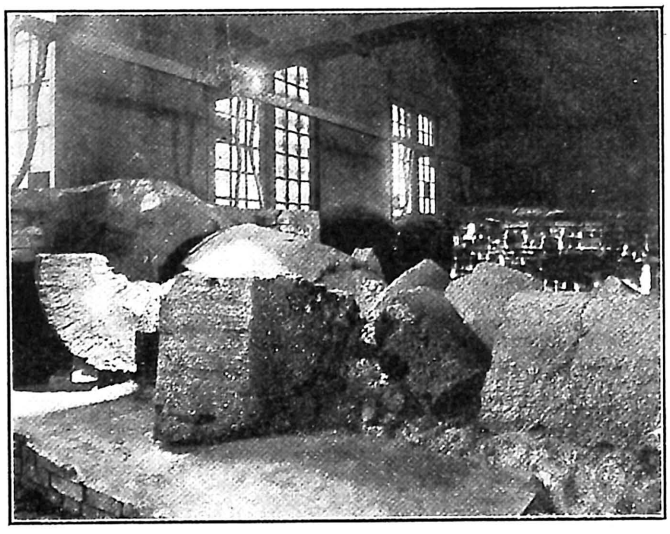


A CARBORUNDUM FURNACE.

carbon and clay together, and to crystallize out the carbon, and obtaining some bright blue crystals in this manner, which were certainly not pure carbon, he suspected that they were a compound of carbon and alumina, and constructed for them the name *carborundum*. Analysis, however, showed these crystals to contain 60 per cent. of silicon, 30 per cent. of carbon and only 4.78 per cent. of alumina. Experiments then followed with mixtures of carbon, silica sand and salt as a flux, and large crystalline masses of the new product were obtained. Its hardness suggested its use as an abrasive, since it is nearly as hard as the diamond, and its commercial manufacture as a substitute for emery and corundum soon followed.

The furnaces employed at Niagara Falls are horizontal, and take 1,000 horse-power each. There are two blocks of five furnaces each, of which one furnace in each block is in operation, while the other four are either cooling off, being emptied

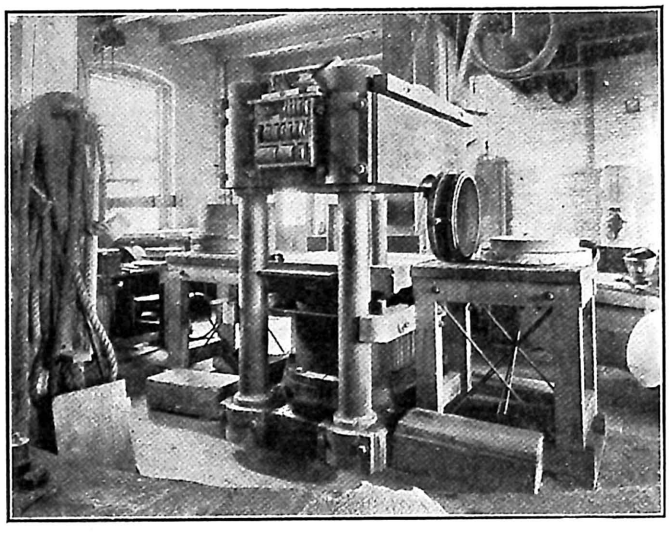
or being loaded up for a fresh run. The bed of fire brick is 16 feet long, 5 feet wide and stands 2 feet above the floor. The ends are of solid brickwork, 2 feet thick and 8 feet high, in the center of which are square iron frames, in which are drilled holes. Through these holes the strands of the conducting copper wires pass, and are connected to the terminal carbons, bunched together, which lead the current into the furnace. Directly in contact with these carbons is placed the conducting carbon core, which conducts the current through the furnace



CARBORUNDUM.

and by its resistance raises the temperature sufficiently to reduce the carborundum-making mixture which surrounds it. When charging is completed, the carbon core is surrounded on all sides by the mixture to a distance of 2 to 3 feet, and the top is rounded off like a mound. The electrical connections are now made to the iron frames, at the extreme ends of the furnace, and the charge is ready to burn.

The alternating current of 250 volts is passed into a 830 kilo-watt (1,100 horse-power) stationary transformer, which

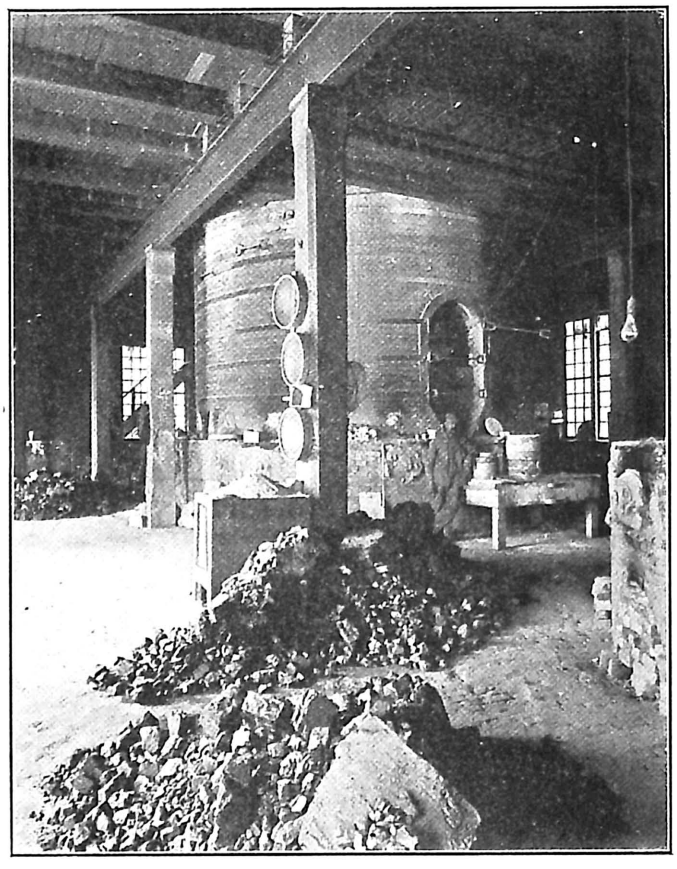


A CARBORUNDUM PRESS.

cuts its voltage down to an average of 185 volts. A regulator allows the current to vary from 100 volts up to 250, while the ampères vary from 2,000 up to 8,000. The 4 per cent. loss in transformation, representing 40 horse-power, would heat up the transformer, but is counteracted by cooling it by circulating currents of oil.

The furnace starts at high voltage and low ampèrage, because of the poor conductivity of the carbon core when cold. The total contents of the furnace are about 1,000 pounds of carbon core, and the mixture reduced represents 3.5 tons of carbon mixed with 6 tons of silica sand and 1.5 tons of salt, producing in a thirty-six-hour run between 3 and 4 tons of commercial carborundum, in crystals, outside of which is a quantity of light-green amorphous carborundum, fully reduced, but uncrystallized, and outside of this the unchanged mixture. Near the carbon core, where the heating is most intense, are found some crystals of carborundum from which the intense heat has volatilized the silicon, leaving a skeleton crystal of graphite, while the silicon, passing outward as vapor, oxidizes to spongy, felt-like silica as soon as it meets carbonic oxide gas. Some of the vapor has been found condensed to metallic silicon in cracks in the bed of the furnace. The observation of the formation of graphite by the very evident decomposition of the silicon carbide, was the starting point of the graphite industry now conducted by Mr. Acheson in an adjacent plant.

A third block of furnaces is now in course of construction, which will raise the power requirement to 3,000 horse-power,



A CARBORUNDUM KILN.

and increase the output of carborundum to 1,800 tons per annum.

The furnace, after a run, is allowed to cool several hours, then gradually uncovered, the unreduced mixture is removed, the reduced, but uncrystallized, carborundum is put aside to be mixed with another charge, and the 10 to 15 inches of well-crystallized carborundum next to the heating core is carefully gathered up. The carbon core serves only as a heating agent; very little of the current during reduction passes through the sand-carbon mixture, which is in reality a very poor conductor of electricity. The process is, therefore, simply that of heating the mixture to be reduced by the heat generated in a carbon conductor, which carries the current and which is surrounded by the mixture. The electric current not only heats up the immense mass of charge, but also supplies the heat absorbed in the chemical reactions involved. A consideration of the power used and the products obtained in one run, leads to the conclusion that about 25 per cent. of the energy of the current is needed to heat the materials up to the

reacting temperature, 50 per cent. in supplying the great quantity of heat absorbed in the chemical process of reduction and only some 25 per cent. is lost by radiation during the run (the 25 per cent. first spoken of is lost by radiation after the run has ended).

The cost of power alone amounts to 1.25 cents per pound of crystals obtained, the cost of materials for the mixture 0.75 cent and labor probably another 0.5 cent, making the estimated cost of crude crystals 2.5 cents per pound. This material must be otherwise treated before being ready for market. This subsequent treatment consists in crushing the masses to coarse powder, allowing this to stand several days in dilute sulphuric acid, to remove any such impurities as iron oxide, then washing and grading. The final cost of the powder or grains may be 4 to 5 cents per pound. It is sold at an average of 9 cents per pound; the manufacture of 2,400,000 pounds yearly providing, therefore, an estimated profit of $100,000 to the company. A large part of the product is, however, worked up by the company themselves into wheels, hones, etc., of all sizes and descriptions, the manufacture of which occupies, with its presses, baking ovens, kilns and stock rooms, the greater part of the floor space in the company's factory. This manufacture is an additional and large source of profit.

The crystals are graded in 20 sizes, from No. 8, passing

INTERNATIONAL ACHESON GRAPHITE CO.

through 8 meshes to the linear inch, to No. 220, passing through 220 meshes to the linear inch. The washings from the finest crystals pass into settling tanks, producing so-called *carborundum flour* of three grades of fineness, F, FF and FFF. The finest powders are made by stirring fine powder or flour in water, letting it settle a definite time, one, four, six, ten or fifteen minutes, decanting the liquid and then settling the powder from this by long standing. Such powders are called *hand-washed* one, four, etc., minute powders.

The factory buildings are two and three stories high, covering three sides of a four-acre plot of ground, and contain 120,000 feet of floor space. They contain costly machinery, presses, drills, etc., for making the carborundum up into wheels, sticks, hones, sharpening stones, cloth, paper, etc. The greater part of these goods are made up with a bond of kaolin and feldspar, which becomes vitrified in the subsequent kiln burning, producing the firmest "body" which can be made.

A particular use to which carborundum has been put is the addition to steel, to secure sound castings, it being thus possible to introduce silicon without bringing a trace of phosphorous or sulphur into the steel. Since the carborundum contains 70 per cent. of silicon to 30 per cent. of carbon, it is very efficient for this purpose.

Immediately in front of the factory is the new office, built in colonial style after designs of Mr. Haskell, president of the company, and one of the prettiest office buildings in Niagara.

The International Acheson Graphite Co.

Manufactured graphite was suggested as a commercial possibility to Mr. Acheson by finding in the center of his carborundum furnaces masses of graphite resulting from the overheating of carborundum. The making of carborundum is a delicate operation, the proper adjustment of current to core being absolutely necessary for producing a good output. It has been stated that an increase of 3 per cent. in the size of the conducting core, in a carborundum furnace will result in a great decrease in the amount of carborundum formed, because of deficient temperature, while an increase of 3 per cent. above the normal will result in the conversion of considerable carborundum into graphite, by volatilization of its silicon. In other words, the temperatures of formation and of decomposition of carborundum lie somewhat close together, probably not over 500° Centigrade apart.

Having thus an idea of a new principle which was available for producing graphite, Mr. Acheson experimented further, with the result of becoming convinced that all metallic carbides, on being decomposed by heat, leave behind graphite, and his patents and process are based upon that fact.

The company concerned was organized in 1899, with Mr. Acheson, president; A. W. Mellon, Pittsburg, vice-president, and P. McN. Bennie, secretary. The patents by which they work are U. S. Patent 542,982, of July 23, 1895, which relates to the production of pure electric-light carbon by subjecting impure carbon to a high temperature for a sufficient length of time to volatilize its impurities; U. S. Patent 568,323, of September 29, 1896, and 617,979, of January 17, 1899, which disclose the principle of converting carbon into graphite by mixing it with such metallic oxides as would be capable of forming metallic carbides, to be subsequently decomposed; U. S. Patent 645,285, of March 13, 1900, which claims the use for conversion into graphite of such natural carbonaceous materials as contain uniformly intermixed through them metallic oxides sufficient to produce carbides and thence graphite. These patents, taken together, not only form the basis of the commercial manufacture of graphite, but throw much light on the scientific question as to the manner of its formation.

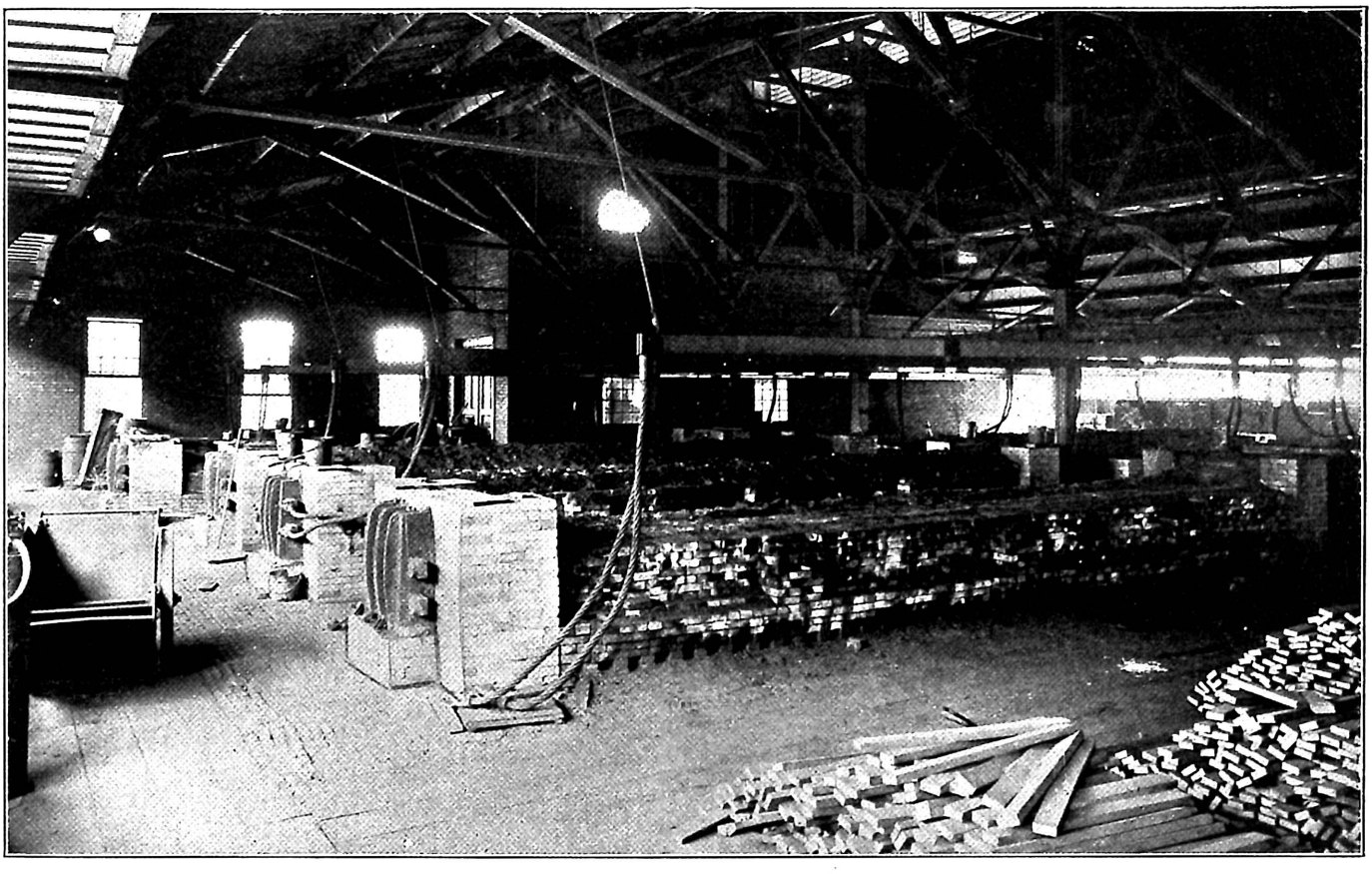
The furnace building is of brick and iron, 100 x 50 feet, and contains two rows of five furnaces each. Back of this is a frame building with machinery for grinding coke and coal, and making the furnace mixtures. The power used is 1,000 horse-power, converted down from 2,250 volts to an average of 150. The blocks are run very much like carborundum furnaces, in that while one furnace is being run, the four others are in various stages of dismantlement or re-filling. The commercial work of the company has resolved itself into two lines of manufacture: (1) the graphitization of molded carbons, (2) the graphitization of anthracite coal *en masse*. The product is, in either case, pure graphite, which should be known as *manufactured* graphite rather than *artificial* graphite, since it is no counterfeit of graphite, but the real graphitic carbon itself. A good summary of the history of the invention, by Mr. Acheson himself, may be found in the *Journal of the Franklin Institute,* for June, 1899, and a discussion of the value of the resulting product, by Mr. Collins, in the *Transactions of the American Electrochemical Society,* Vol. I, 1902.

The conversion of molded carbon articles into graphite is performed by stacking them transversely to the current in a pile about 2 feet square, between terminals 30 feet apart, and covering them thickly with fine granular carbon and carborundum. A quite recent patent to Mr. Acheson (U. S. Patent 702,758, of June 17, 1902), has for its subject-matter the particular manner of stacking such articles for graphitization, the granular carbon between the articles being the principal heat-producing agent, while the heat generated in the articles themselves is of secondary value because of the transverse position of the articles. By this arrangement the furnace charge offers such resistance to the current that it may

be held at a very high temperature, while the conducting terminals, of solid carbon, but of much smaller cross section than the furnace charge, are at only a moderate temperature. (This is also discussed by Townsend in the *Electrical World*, of June 28, 1902.) The current is then put onto the furnace, at 220 volts and 3,000 ampères to start with, and gradually increasing to 80 volts and 9,000 ampères at the end of a twenty-hour run. At the close of the run the furnace is allowed to cool off several hours before uncovering. The heat is thus sufficient to graphitize the furnace charge completely and also even some of the outer packing of granular carborundum. If the articles have not been heated sufficiently, they will still contain some amorphous carbon, which will dissolve in acids and alkaline solutions, and disintegrate the article; if they are overheated they may become too dense and develop cracks on cooling or subsequent use. Many hundred thousand of carbon electrodes, 15 inches long by 1 inch cross section, used in the liquid caustic alkali process, have been made in this way, and have given such satisfactory service that Mr. Acheson's business has really suffered by the surprising long life (one to two years) of these electrodes and the consequent lack of renewals. Blocks, 8 inches by 10 inches and 4 inches thick, as well as rods, 4 inches square by 24 inches long, have been perfectly graphitized in these furnaces.

Since three to three and a half tons of material can be graphitized in one charge, with nearly an equal amount of granular carbon and carborundum on the furnace, we can calculate, from a consideration of the current used, that it would take the current used over sixteen hours to bring the furnace up to the volatilizing point of carbon, which is not far above the temperature of graphitization. The current being run for twenty-four hours, it follows that just about one-third of the total heat energy of the current is radiated or conducted away during the run, while two-thirds are represented by the heat in the hot furnace at the end of the run, the heat in the actual articles being graphitized being 40 per cent. of the heat energy of the current. The conversion of amorphous carbon into graphite is, of itself, a heat-evolving reaction, such that the graphitization of 7,000 pounds of carbon would represent $7{,}000 \times 236.5 = 1{,}655{,}500$ pound-calories (1° C.) or some 5.7 per cent. of the energy which the current furnishes, but against this can be set the heat necessary to reduce metallic oxides and dissociate carbides, which will be a factor of about the same value.

As to the articles thus graphitized, they possess a specific resistance of but 0.00032 ohm per cubic inch, which is but one-fourth that of amorphous carbon. (This specific resistance is 0.0008 ohm per cubic centimeter, and since that of mercury is 0.000094 ohm, the conductivity is 11.75, mercury being 100, or 0.21, copper being 100). As for durability, such carbons have been used as anodes in alkaline chloride solutions for three years, with a current density of 50 to 250 ampères per square meter, without as much as rounding off the sharp edges. In electric-furnace work, at high temperatures, the consumption by oxidation is one-fourth, or less, that of amorphous carbons under similar circumstances, making their use in many cases very advantageous.



GRAPHITE FURNACES, ACHESON GRAPHITE CO.

The other line which the electrical manufacture of graphite has taken, is the conversion of carbon in bulk into graphite. For this purpose some carboniferous material is taken which has a considerable quantity of ash, or metallic oxide impurities, uniformly distributed through it. The purest carbon, such as petroleum coke, which contains only 0.3 per cent. of ash, graphitizes very poorly; similarly, ordinary coke will graphitize completely only where the ash is uniformly distributed, but those parts of the coke which have been formed from the baking of exuded pure bituminous matter are too pure to graphitize and yield a poorly-converted product. Clean anthracite coal, such as washed *pea* or *buckwheat* coal, are the best adapted, and give very satisfactory results, for in them nature has distributed 5 to 15 per cent. of ash with almost molecular uniformity.

The furnace for this conversion is 30 feet long and is formed of a trough 2 feet square, lined on bottom and sides with blocks

of compact carborundum 6 inches thick. This is found to be a very satisfactory lining for high-temperature electric furnaces, to build walls in places where the best fire brick would melt like water and carbon bricks would be subject to oxidation. The coal is ground to about the size of rice and the furnace trough first half filled. Graphite rods are inserted in the ends, to conduct the current into the mass, and a core of granular carbon, partly graphitized, about 6 inches wide, is laid from one end to the other, in order to start the current, since cold anthracite is of itself so poor a conductor that, otherwise, it might be impossible to start the current flowing with the maximum volts at command. The furnace is then filled up, and a layer of coarse carbon and granular carborundum placed on the top. The charge of anthracite is about six tons, and it is graphitized in twenty hours. A consideration of the energy of the current and the amount of material treated lead to the conclusion that about 82.5 per cent. of its energy is consumed in raising the charge to the graphitizing temperature and 17.5 per cent. radiated during the run; or, stating it another way, it requires theoretically sixteen hours and thirty minutes' running to bring the whole charge up to the graphitizing temperature, and the rest of the twenty hours is used in keeping it there and supplying radiation. The heat *evolved* in conversion of amorphous carbon into graphite amounts in this case to fully 10 per cent. of the heat supplied by the current, but this is just about balanced by the heat absorbed in volatilizing the 5 to 10 per cent. of impurities from the coal.

The amount of unconverted amorphous carbon is most easily estimated in the laboratory by attacking it with concentrated nitric acid at 86° C., when the brown coloration of the liquid gives the means of estimating the amorphous carbon present. Natural graphite contains some amorphous carbon, say 0.1 to 0.2 per cent.; the manufactured graphite from anthracite coal may contain up to 2 per cent., the graphitized articles to which have been added iron oxide to facilitate conversion, contain often as little as the native graphite.

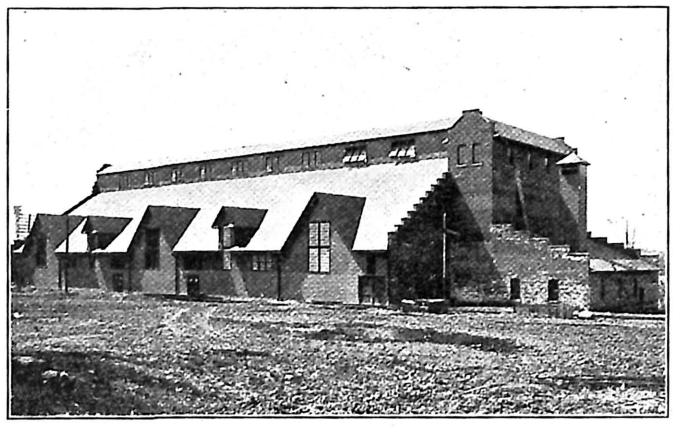
Many kinds of graphite may be produced from different carbonaceous materials treated in different ways and crushed afterwards in different manners. There is the soft and the dense, the laminated, foliated and stratified kinds, the fibrous, like Ceylon *wood* graphite and the scaly, like Ticonderoga graphite. Different kinds are suitable for different purposes; the scaly for crucibles and lubricating purposes, the dense for hard lead pencils, the soft for foundry facings, stove polishes and iron-protecting paints. The total yearly production of this factory is nearly 1,000,000 pounds, at an average value of 8 cents per pound; graphitized electrodes are valued at 12 to 15 cents per pound and graphite in bulk from 10 down to 4 cents, according to purity and flakiness, and the product represents a considerable fraction, some 20 per cent. of all the graphite produced in America.

The Acker Process Co.

The projectors of this company are the brothers C. E. Acker and A. E. Acker, who began in 1894 experimenting at the problem of electrolyzing melted sodium chloride, and producing thereby caustic soda and chlorine. An extensive description of the process which has been evolved, written by C. E. Acker, is in the *Transactions of the American Electrochemical Society*, Vol. I, 1902. The patents under which the company work are U. S. Patents 649,565, of May 15, 1900; 674,691, of May 21, 1901, and 687,709, of December 3, 1901, to Chas. E. Acker.

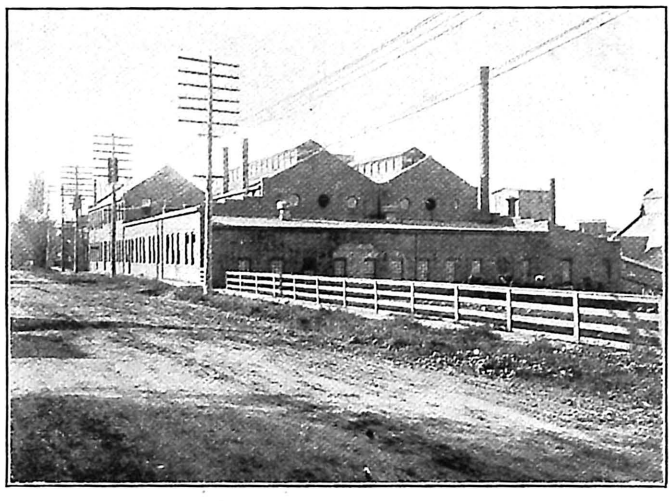
The plant established at Niagara Falls is situated 1,500 feet below the lower power house, on a 10-acre piece of ground, and comprises a large reduction room, some 80 by 150 feet in plan, a still larger building of brick and iron for the bleaching powder plant, besides an extensive machine shop, brass-casting foundry, pattern shop and large offices. Some 250 men are in the company's employ.

The idea of Acker's process, and elaborated in his patents, is the electrolyzing of melted sodium chloride resting upon melted lead, the latter serving as cathode. The lead-sodium alloy is then decomposed by a jet of steam in another part of the same apparatus, producing melted caustic soda, which flows away and hydrogen which immediately burns. The process is carried on in a heavy cast-iron vessel, 5 feet long, 2 feet broad, with a bowl about 12 inches deep. The sides, above the surface of the melted lead lying on the bottom, are protected by a lining of magnesia blocks. At one end is a small compartment separated by a partition dipping below the level of the lead, into which the lead alone can pass and in which



ACKER PROCESS CO.

it meets a jet of steam blown directly into it, which oxidizes the sodium to caustic. On top of the lead a bath of sodium chloride is melted, about 6 inches deep, into which dip four graphitized carbon blocks serving as anodes. The lower surface of these blocks are 14 inches long by 7½ inches wide, and reach to within ¾ inch of the melted lead. The blocks are 3 inches thick and are kept in place by heavy 5-inch round graphitized carbons, 12 inches long, two of which are screwed into each carbon block. The upper end of these rods are encased in fire-brick tiles, which, when in place, form part of the cover of the furnace, and electrical connection is made by



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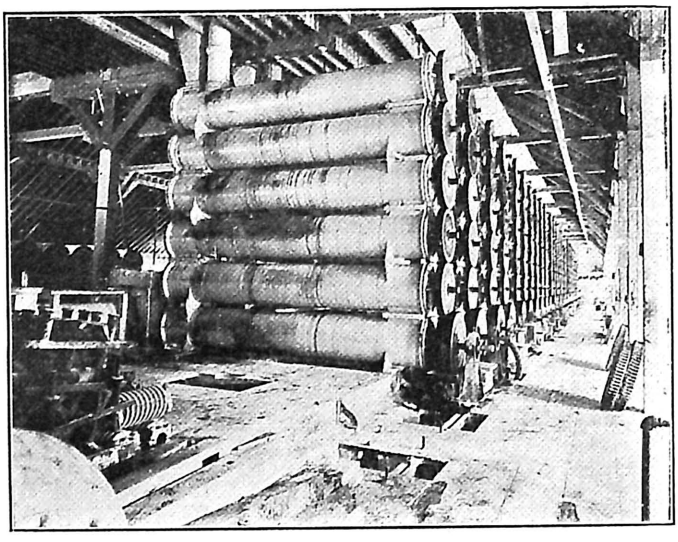
means of heavy brass rods, 1½ inches in diameter, tapped into them, and connecting further up with copper rods, which are held by clamps to the bus bar above. The 5-inch rods are protected by fire-clay sleeves, joints are plastered over with cement. The top of the furnace is further loosely closed by fire-clay slabs, but the joints need not be very tight, since the chlorine is drawn away by side flues by a strong exhaust, making the escape of chlorine into the room impossible. The

salt to be used for charging comes through a hopper from the floor above, and is piled between the furnaces and on part of the cover, so as to become dry and warm before being charged.

The pot room has place for 54 furnaces, in four rows, of which 40 to 45 are in action while the others are undergoing repairs. The current of 3,000 horse-power is sent 1,500 feet from the generating station as direct current of 8,200 ampères, reaching the works at a potential of 275 volts, the cables in the conduit being half the way copper and half aluminum. The pots are all run in one series, so that the drop of voltage is between 6 and 7 volts per pot. The four electrode blocks carry, therefore, about 2,100 ampères of current each, which gives a current density at the lower surface of approximately 2,750 ampères per square foot. This keeps the temperature of the bath at 850° C., a cherry red, which is 75° above the melting point of the salt. The object in conducting the process is to keep as nearly as practicable to the melting point of the salt, in order to avoid the re-solution of sodium and the re-combination which takes place at higher temperatures. The melted salt looks slightly syrupy, and has a silky sheen like melted metal. The workmen regulate the temperature by raising or lowering the electrodes and by charging fresh salt as



BLEACHING POWDER CYLINDERS, ACKER PROCESS CO.

the level of the bath sinks, and they have frequently to break with a bar the crust which solidifies between the carbon rods. The salt is from the neighboring New York salt beds, costs $3 per ton and is not purified before use. The bus bars, for carrying the current, are of copper, and of 9 square inches section, giving 900 ampères per square inch, which is very ample carrying capacity, since aluminum conductors, with only two-thirds the conductivity, are sometimes loaded quite as heavily.

The steam jet, in the compartment at the end of the pot, is introduced beneath the surface of the lead, but pointing vertically upwards. The jet strikes a curved hood, which brings the material down into a third compartment, about 6 inches by 10 inches in area, in which the lead and caustic separate, the latter flowing out of the furnace over a cast-iron lip, the lead sinking and passing back into the reduction compartment of the furnace, while the hydrogen evolved issues from the spout, burns and is conducted away by a 6-inch sheet-iron pipe to a chimney. The melted caustic runs into a sheet-iron pan, where it sets, and is removed every hour. The average output of a furnace is a 25-pound cake hourly. The theoretical amount of caustic which the current should produce being 26.9 pounds per hour, in each pot, the average efficiency obtained is thus seen to be 93 per cent. The voltage used, however, is the other factor of the process which needs considering. There is required, theoretically, 4.2 volts to decompose sodium chloride into sodium and chlorine, but since the sodium unites with lead with great avidity, it is probable that the production of the alloy requires 3.5 volts. Since 6 to 7 volts are used per furnace, we have an average of 3 volts converted into heat. Of this heat evolved, calculation shows that one-sixth is utilized in melting the fresh salt added, while five-sixths is lost by radiation and conduction, and resistance of conductors and connections. Or, considering the whole energy of the current, we may say that 54 per cent. of it is utilized in the chemical reaction, 7 per cent. in melting the salt added and 39 per cent. is lost by radiation and conduction.

The cakes of solidified caustic are taken out of the pans and slide down a chute directly into the cast-iron melting pots, 8 feet in diameter. Here it is melted, allowed to stand six hours to settle and bailed out into sheet-iron drums, 2 feet in diameter by 4 feet high, holding 750 pounds each. The total product is 23,000 pounds of caustic per day.

The chlorine gas is drawn by a powerful fan, 15 feet in diameter, motor driven, through a series of 30 Hassenclever absorption apparatus, each consisting of six drums above each other, 2 feet in diameter by 20 feet long, in which screens revolve slowly in alternate directions. The 50 pounds of slaked lime fed per hour into the upper cylinder is gradually passed by the screw motion from one cylinder to the other, until in twenty-four hours it arrives at the discharge hopper, while the chlorine gas, mixed with air, passes in the opposite direction through the apparatus and into a scrubbing tower beyond, where the last traces of chlorine are removed. The total plant takes care of 21,000 pounds of chlorine daily, requiring 36,000 pounds of slaked lime and producing 57,000 pounds of bleaching powder.

With salt costing $3 per ton and power $15 per horse-power per year, the cost of raw material for making a ton of caustic soda is $4.50, the cost of power $11, steam and remelting 50 cents, labor and repairs probably $14 or an estimated total of $40, which is to be diminished by the value of the chlorine for making bleaching powder. Every $1 per ton profit made on the sale of the bleaching powder would mean $2.50 per ton reduction on the net cost of the caustic. Compared with the aqueous processes, Acker's process consumes more power and costs more in replacement of apparatus, but takes less expensive plant and apparatus, and dispenses with the boiling down of the caustic solutions.

We wish success to the manufacturers in both lines.